GLACIAL OUTWASH TERRACES OF THE HOCKING AND SCIOTO RIVER VALLEYS, OHIO

JOHN P. KEMPTON AND RICHARD P. GOLDTHWAIT
Illinois State Geological Survey, Urbana, and *The Ohio State University, Columbus 10*

A study of the outwash terraces of the Hocking and Scioto Valleys has led to some interesting facts which aid in unraveling the glacial history of south-central Ohio, particularly the Scioto lobe of the Wisconsin stage. This paper is an attempt to relate the various terrace systems of both valleys to each other and to the fluctuations of the several glaciers which covered the central part of Ohio during the Pleistocene. It also should aid future workers in dating and correlating the terraces of the Ohio River Valley, into which outwash materials from the Hocking and Scioto Valleys were carried.

The area studied (fig. 1), in south-central Ohio, follows the valleys of the Hocking and Scioto Rivers and portions of two of their major tributaries, Clear Creek (Hocking) and Paint Creek (Scioto). Detailed study of the Scioto Valley outwash was not carried north of Circleville in Pickaway County but may be found in reports on Pickaway County (Schuster, 1952) and Franklin County (Schmidt, 1958).

Reference has been made to the outwash in the major valleys of Ohio many times by geologists. The outwash has been used, particularly, as evidence of the age of drainage changes which have taken place along the major streams in southeastern Ohio. A good summary and a complete list of references on the work done on these drainage changes up to 1943 can be found in Stout et al. (1943). Andrews (1860) was probably the first to mention outwash in southern Ohio valleys. Tight (1900, 1903) studied the drainage changes in southeastern Ohio with some mention of the outwash in the valleys. Others who have referred to the presence of outwash in the valleys include Andrews (1874), Stearns (1899), Leverett (1902, 1942), Hyde (1912), Stout and Lamb (1938), and Foster (1950). Hyde (1921) discusses, in some detail, Illinoian and Wisconsin outwash in the Scioto Valley within the Camp Sherman Quadrangle, and Merrill (1950, 1953) has defined various levels of Illinoian and Wisconsin terraces in the Hocking Valley within Hocking County. Outwash terraces in the Hocking were studied even more extensively by Kempton (1956). Hubbard (1954) has given a brief summary of terrace relationships in the Ohio, Muskingum, Hocking, and Scioto River Valleys, and indicates the presence of Illinoian and Wisconsin outwash in both the Hocking and Scioto Valleys.

Hocking Valley Terrace Systems

Five terrace systems appear to be present in the Hocking Valley. Since they fall into three groups both by level and soil, they may represent as many as three stages of Pleistocene glaciation. These terrace systems have been identified mainly by soils (fig. 4) and by plotting profiles based on the elevations of each terrace segment (fig. 3). Stonecounts were of aid in stratigraphic identification of the two lowest terrace systems.

Pre-Illinoian stage.—Although pre-Illinoian glaciation extending to southern and southeastern Ohio has not as yet been definitely established, two lines of evidence in the Hocking Valley point to such a glaciation.

Two terrace remnants composed of strongly weathered sand and gravel with a strong red color are present in the Valley. Both contain a mixture of foreign pebbles. One of these, about two and one-half mi west-southwest of Logan in Hocking County (fig. 2), lies between Dry Run and Clear Fork (SW ¼ Sec. 16

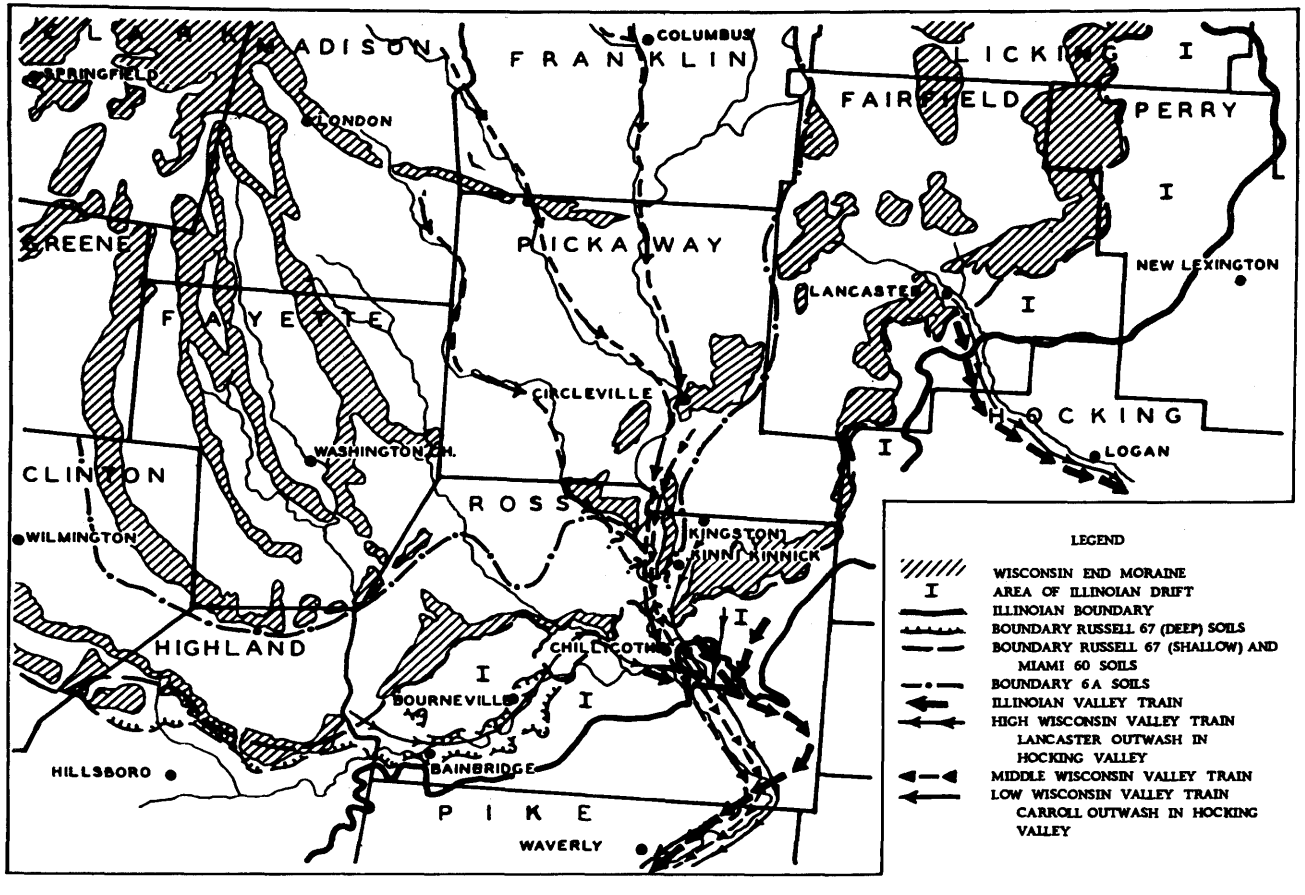
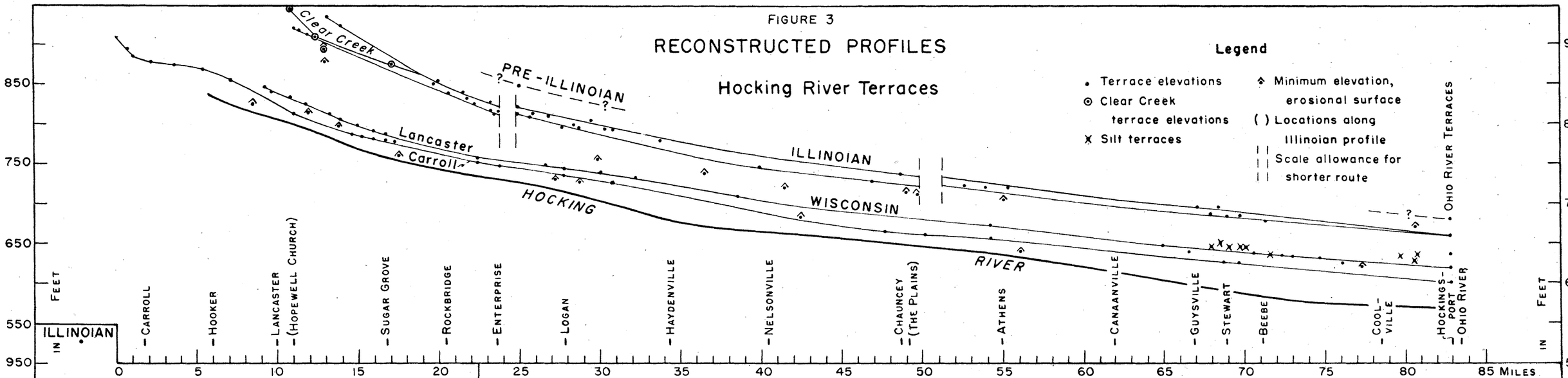


FIGURE 1. Glacial geologic map of central Ohio, showing portions of Scioto and Hocking Rivers and major tributaries.

FIGURE 3

RECONSTRUCTED PROFILES

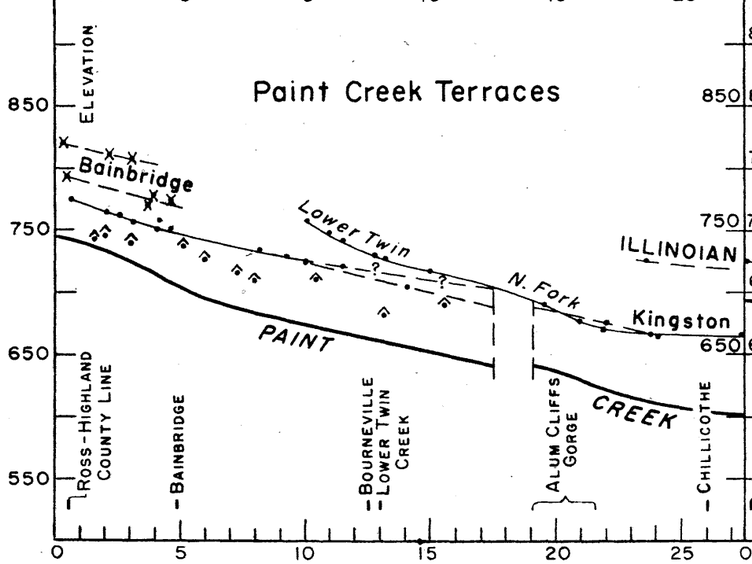
Hocking River Terraces



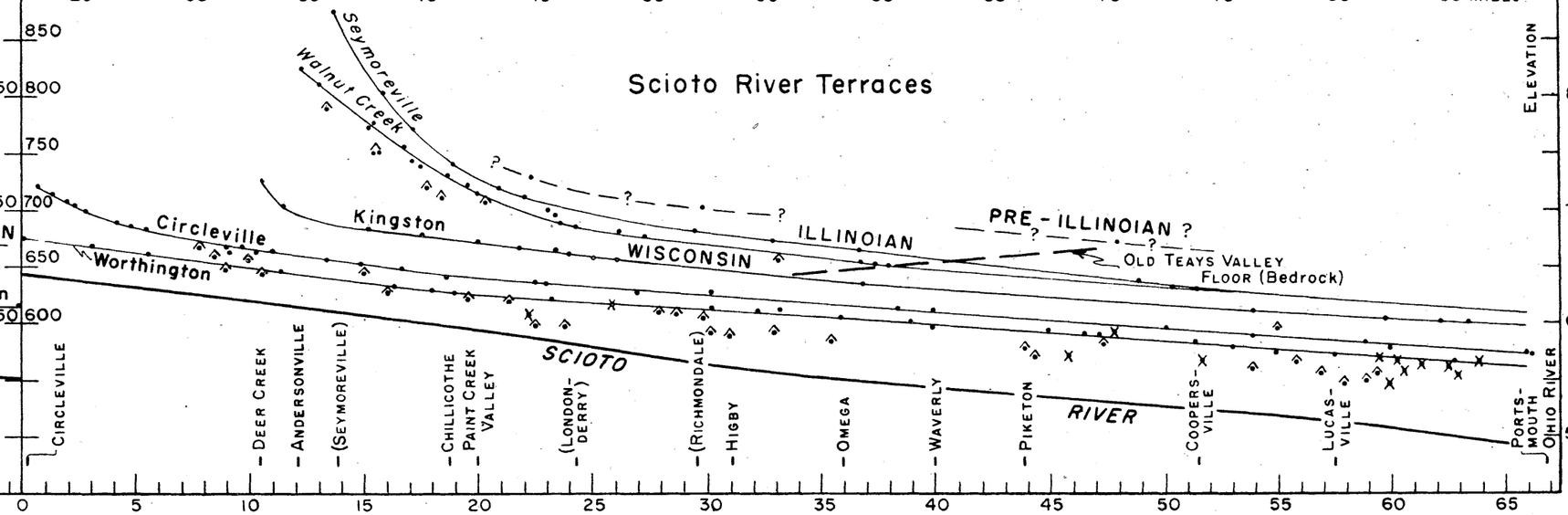
Legend

- Terrace elevations
- Clear Creek terrace elevations
- Silt terraces
- Minimum elevation, erosional surface
- ( ) Locations along Illinoian profile
- Scale allowance for shorter route

Paint Creek Terraces



Scioto River Terraces



Falls Township). The surface of this remnant is somewhat rounded with the highest part at an elevation of 850 ft, at least 23 ft higher than the highest of several extensive Illinoian terraces in the immediate area (fig. 3). The other patch of gravel is located within the bend of the Hocking Valley about one mi south of Coolville and two and one-half mi northwest of the Ohio River on the east bank (fig. 2) and is well exposed along State Route 144. Profiles projected from the Illinoian terraces in the vicinity of Stewart indicate that the maximum elevation of this remnant may be slightly higher than the Illinoian outwash at this point (fig. 3).

The red soils developed on each remnant are similar to those formed under long subtropical weathering conditions. In each case only local sandstones, rotten igneous and metamorphic, and siliceous rock types are present, embedded in a sticky clay-rich matrix. Calcareous or unoxidized gravel was not exposed at either locality, but leaching and oxidation have progressed to a depth of at least 15 ft in both cases.

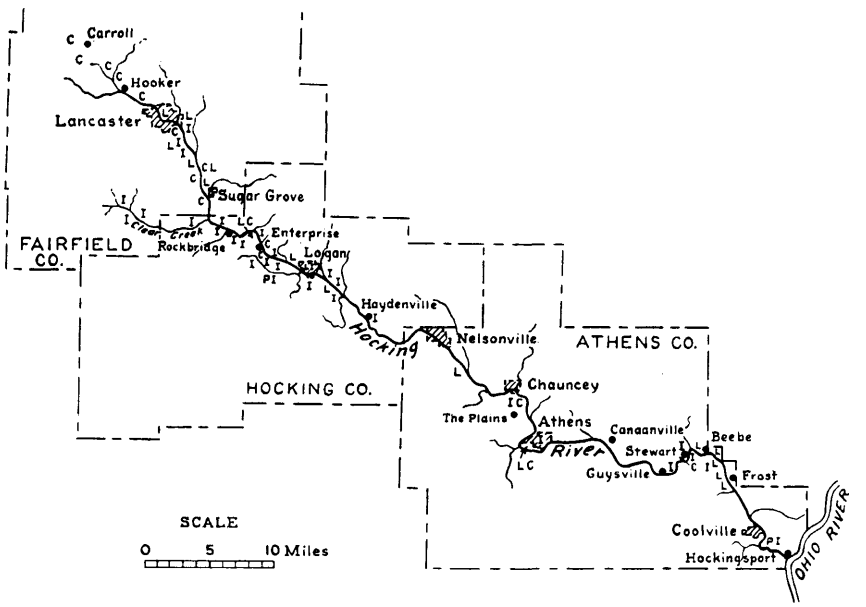


FIGURE 2. Map of Hocking River and portions of major tributaries, showing approximate location of larger terrace remnants: PI, pre-Illinoian; I, Illinoian; L, Lancaster; C, Carroll.

Merrill (1950, 1953) described erratics high on the hills above Rockbridge, considering them mainly Illinoian terrace remnants. However, the profile of the Illinoian outwash, traced from the source area in Fairfield County, falls at a level much lower than the elevation of most of these erratics. Since there is yet no conclusive evidence of Illinoian ice having advanced as far as Rockbridge, it remains a possibility that some of these erratics are the only remaining traces found thus far of pre-Illinoian ice or water-laid deposits.

Illinoian stage.—Two terrace systems are present in the Hocking and Clear Creek Valleys which are interpreted as representing outwash deposited during the Illinoian stage of glaciation. These terraces constitute the most numerous and extensive outwash deposits preserved from Lancaster in Fairfield County to the Ohio River in Athens County (fig. 2). Especially notable are the extensive areas of smooth-topped terrace between Rockbridge and Logan and "The Plains" just

northwest of Athens. Since both are in abandoned sectors of the Valley where the present Hocking flows in a narrower, somewhat longer course than that occupied by the Illinoian outwash, breaks have been necessitated in the Illinoian profile in figure 3.

The profile of the Illinoian terraces (fig. 3) indicates that there may be two terrace systems at least at the upper (north) end of the valley. Although elevations of most terrace segments group around one profile, a great difference in elevation between segments just south of Lancaster suggests two stages of outwash deposition. Also the slight but consistent variations in elevation, up to 20 ft down the valley to Beebe, is suggestive of two levels. However, the levels may have converged at some point between Rockbridge and the Ohio River, with subsequent erosion obscuring the exact area of convergence. Differentiation of two levels on a soils basis was impossible due to the great length of time during which soil development has progressed.

The soils developed on the Illinoian terrace remnants (fig. 4) are deep, having been leached an average of 15 ft and oxidized as much as 20 ft. Up to five ft of yellow-brown silt and fine sand (loess) are present over the weathered gravel on some terraces. These soils, called Park (or Hocking) are generally dark reddish-brown to yellowish-brown in color. Most of the upper five ft is clayey (B horizon), and contains only rotten and decomposed igneous, metamorphic, and siliceous pebbles and occasionally carbonate pebble "ghosts." In most deep exposures, cementation of the gravels by secondary carbonate produces large projecting blocks below the leached zone.

Counts of 100 one to three in. pebbles from nine Illinoian terrace remnants along the valley averaged 37 percent carbonate and associated rocks, 39 percent local sandstones and shales, and 24 percent crystallines, but great deviation occurred in four of these counts. Carbonate analyses of the sand, silt, and clay fractions from the outwash of eleven Illinoian terraces yielded an average of 22.4 percent total carbonate content with only three samples deviating much from the average and ranging 5.5 to 32.0 percent.

The bases for relating the outwash terraces described above to the Illinoian stage are: 1) the 20-ft depth and clayey character of the soils developed on the terraces; 2) much higher elevation (40 to 90 ft) of both terraces in relation to the Wisconsin terraces; 3) depth and extent to which the original surface has been trenched in both the main and local valleys; 4) tracing of the terrace systems to their sources just inside the Illinoian drift border; and 5) steepening of gradient from about 4 ft per mi downvalley to about 13 ft per mi at the Illinoian border.

Probably the most reliable means to date these terraces was tracing them to their source inside the glaciated area of Fairfield County. Two principle source areas are indicated by the field mapping (fig. 2): one near Lancaster in the Hocking Valley and one just east of Clearport in Clear Creek Valley. There may have been a third source near North Berne, east of Lancaster and down Raccoon and Rush Creeks, but this has not been mapped in detail. The terrace systems in all valleys head inside the Illinoian drift border (fig. 3) as mapped by Leverett (1902), White (1939), and more recently by Conley (1956).

The major source of outwash appears to have been in the vicinity of Lancaster at the beginning of the narrow bedrock restriction of the Hocking Valley. Two terrace levels are present, the highest at an elevation of 935 ft, begins about two and one-half mi down the valley from Lancaster on the west side of the valley while the lower heads at an elevation of 920 ft at the southeastern limits of the city. The valley train of Clear Creek probably headed about one mi southeast of Clearport at Hopewell Church and entered the Hocking Valley at the higher Illinoian level about two mi northeast of Rockbridge in northern Good Hope Township, Hocking County (fig. 2 and 3).

Wisconsin stage.—Two low terrace systems comprise the valley train deposits

which have been laid down in the deep trench cut into the Illinoian valley train. Merrill (1953) made no specific distinction between these two terrace systems although he does indicate at least two levels on profiles.

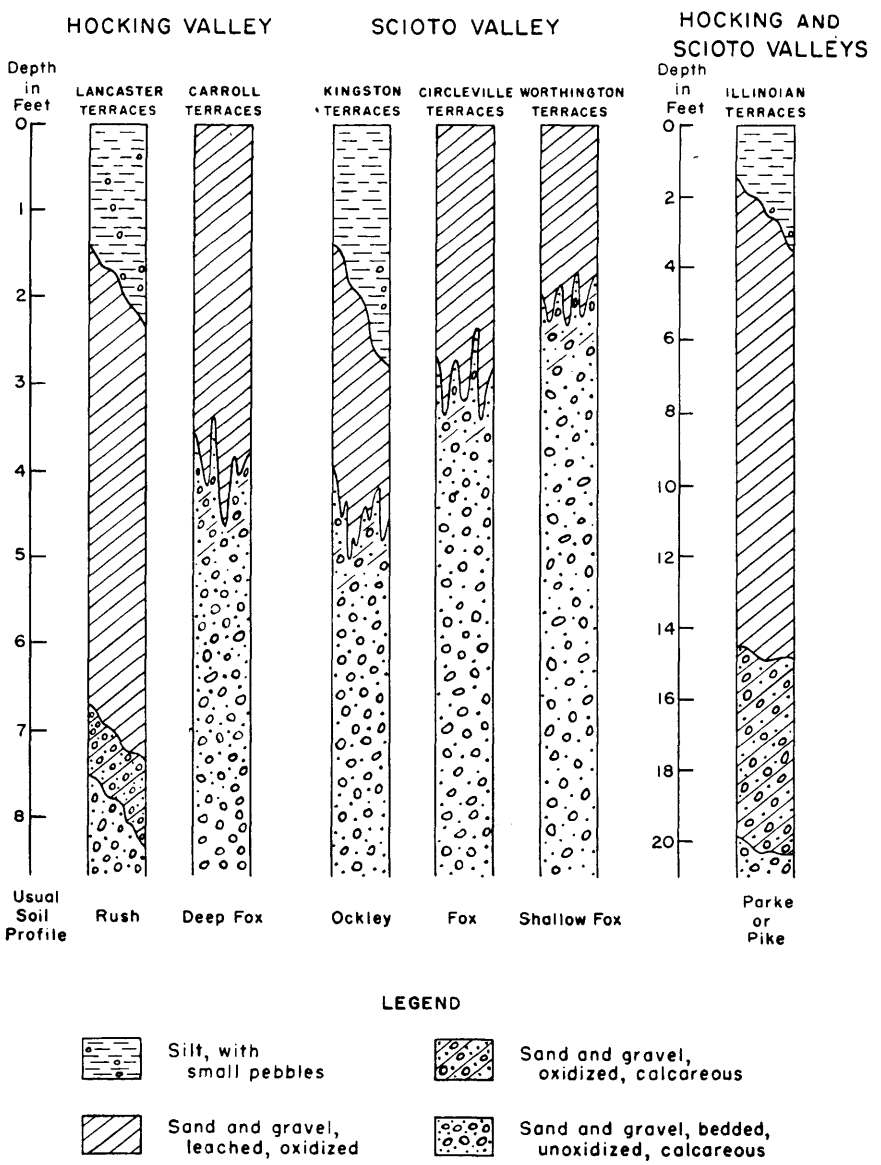


FIGURE 4. Generalized diagrams of terrace soils.

The higher of these two terrace systems heads at Lancaster in Fairfield County, at the outer edge of the Wisconsin terminal moraine, and is found at various points along the Hocking Valley to about six mi from the Ohio River (fig. 2). Much of the City of Lancaster rests on this terrace. For this reason it will be called the Lancaster terrace system.

The soil developed on the Lancaster terrace (fig. 4), particularly in Fairfield and Hocking Counties, are deep, with a characteristic chocolate-brown color. This is probably Rush type soil. In most cases a light brown pebbly silt covers the gravel to a maximum thickness of two and one-half ft. Oxidized gravel generally extends to a depth of about eight to ten ft below the surface. Where the original smooth surface is preserved, the depth of the leached zone generally extends to about 90 in. below the surface. In Athens County, below the City of Athens, the aspects of the soil and terrace materials change somewhat. The composition of the outwash becomes finer and is interbedded with thin layers of blue-gray clays. The soil is deeper, with the materials oxidized and leached as deep as 20 ft.

Identification of remnants of this terrace system was aided by stonecounts of a hundred one to three in. pebbles which consistently gave counts varying only a few percent from: 46 percent calcareous rocks, 38 percent clastic (mostly local sandstone and shale), and 15 percent crystallines. Carbonate content of everything smaller than 2 mm averaged 26.1 percent. Most of the terraces which retain constructional surfaces fall on a fairly smooth profile (fig. 3). In one instance where a terrace remnant was not easily identified, information from a local resident indicated that an old gravel pit had been abandoned because there was too much overburden to remove.

An excellent exposure of a terrace of the Lancaster system is situated in a gravel pit at the northwest edge of Logan (NE ¼ Sec. 10 Falls Township, Hocking County) in the mouth of a small tributary valley to the Hocking. The evelation of its surface is 748 ft.

		Ft	In.
4.	Yellow-brown silt and fine sand, contains many small pebbles	1	8
3.	Sand and gravel, oxidized, dark reddish brown to chocolate brown, clay rich, many rotten pebbles, pebbles range up to ten in	5	2
2.	Sand and gravel, oxidized, chocolate brown, calcareous, clayey with many rotten pebbles	3	2
1.	Sand and gravel, gray to brown, unoxidized, many rotten pebbles, calcareous, a few lenses of leached gravel present, base not seen	20±	0

This exposure is typical of the Lancaster system above Athens. Below Athens a typical exposure occurs in a road cut about three mi east of Stewart, in the extreme southeast corner of Sec. 3 Rome Township, Athens County.

		Ft	In.
5.	Gray-brown fine sand and silt	1	0
4.	Fine sand, yellow-brown	4	0
3.	Alternate layers of fine and medium sand, dark yellow-brown to chocolate brown	10	0
2.	Coarse to medium sand, chocolate brown, clay rich, two 2-in. layers of hard gray-brown to tan clay interbedded with sand, leached to base	5	0
1.	Gray, coarse to medium sand, containing numerous small pebbles under ½ in., calcareous, base not seen	5	0

The gradient of the Lancaster terrace system throughout its entire length averages about three ft per mi. The upper 13 mi has a gradient of seven ft per mi and gradually steepens at the head in the vicinity of Lancaster to 16 ft per mi. This indicates that the source of the outwash was probably at Lancaster.

The lower of the two low terrace systems heads further northwest in kames

and kame moraine about two mi northwest of Carroll, Fairfield County. It begins as a kame terrace, merges into an outwash plain and then becomes a valley train at Lancaster. Patches of this terrace system are present at scattered localities along the valley as far as Stewart in Athens County, southeast of which it apparently has been completely removed. It is called the Carroll terrace system for exposures at its head near Carroll.

The Carroll outwash contains a high percentage of calcareous gravel as indicated by three stonecounts. These show that the pebbles from the gravel average 67 percent calcareous and associated rocks types, 24 percent clastic, and 9 percent crystalline, very different from both the Illinoian or Lancaster terraces. Carbonates in the sand-silt-clay sizes were also higher, averaging 29.9 percent (ranging from 19.2 to 38.5 percent).

Exposures of the soil developed on the constructional surface of the Carroll terrace are rare, particularly in Athens County. Thus, numerous auger borings were used to supplement information from the exposures and to identify the terraces on a soils basis. A most pronounced feature of these soils is a wavy pendantlike line separating the leached, clayey, reddish-brown B horizon from the little-oxidized calcareous sand and gravel (fig. 4). The depth of leaching and clay concentration (B zone) varies greatly in a short distance due to the pendants, but generally averages about 48 in. in the upper part of the valley in Fairfield and Hocking Counties. In Athens County the depth of leaching is generally greater than 50 in. The soil itself consists primarily of dark reddish-brown oxidized clay-rich sand and gravel with an average thickness of 41 in. overlain by about seven in. of gray-brown sandy silt (A zone). The color and composition of the soil, including the pendants, are typical of the Fox catena. However, they are somewhat deeper than typical Fox soils, which usually range from 27 to 40 in. (leaching).

A typical exposure of the Carroll terrace soil and gravels is present in a gravel pit along a narrow portion of the valley about a mile north of Enterprise (SW ¼ NE ¼ Sec. 31 Marion Township, Hocking County).

		Ft	In.
6.	Sand and gravel, dark reddish-brown, clayrich, noncalcareous	3	10
5.	Sand and gravel, gray-calcareous, with oxidized, noncalcareous pendents numerous extending from zone 6	1	0
4.	Silt and fine sand, gray-brown, calcareous	0	6
3.	Sand and gravel, gray, calcareous, oxidized pendents numerous, noncalcareous	1	6
2.	Silt and fine sand, gray-brown, calcareous, massive	1	10
1.	Sand and gravel, gray, calcareous, with a few large cobbles up to two ft across, base not seen	14	0

Distinguishable remnants of these terraces are scarce below Logan (Hocking County), and thus the nature of the original outwash profile below Logan is questionable.

Lacustrine deposits.—Sediments consisting primarily of silt and clay are associated with the terrace systems in the valley. These deposits are present in many valleys tributary to the Hocking and also at numerous localities in the lower part of the Hocking Valley itself below Athens.

The lake sediments in the lower Hocking Valley are generally present in the form of flat-topped terraces along the main valley walls. The same type of sediments is also present in the tributary valleys in this area, such as Federal Creek. Paschall et al. (1938) mapped the soils developed on these terraces as the Wyatt silt loam. Where typically exposed, these deposits are blue, massive, calcareous, fine silt and clay, with occasional laminated beds present. Size analyses

of many samples of these deposits show that they contain no more than 5 percent sand. Small calcareous concretions up to one-fourth in. in long dimension occur in some of the massive deposits below the soil zone. Carbonate content ranges from 21 to 71 percent. Depths of leaching range from 26 in. to 52 in., with 26 to 36 in. the most common.

The close association of these lacustrine deposits with the Lancaster terraces points to deposition of both during approximately the same interval of time. The tops of the lacustrine terraces range from about 630 to 645 ft in elevation, which is the same range as the Lancaster terraces in the area. Also, Lancaster terrace remnants in this area contain many interbedded layers of clay and silt similar to the lacustrine clay and silt. From this evidence, it appears that while the lower Hocking drainage system was ponded (mechanism as yet not understood), outwash was building up progressively down the valley below Athens into a lake as a shallow delta. Sand and gravel was deposted during times of excessive discharge from the melting ice at Lancaster, and finer material was deposited while little or no outwash was being carried down the valley.

Above Athens, lacustrine deposits are present in several of the tributary valleys to the Hocking. An excellent example is the valley of Oldtown Creek which contains silt, clay, sand, and marl up the valley for several miles from Logan. Most of these valleys were ponded one or more times as outwash building up in the Hocking Valley blocked the mouths of these streams (Merrill, 1950).

Scioto Valley Terrace Systems

The Scioto Valley contains three outwash terrace systems of Wisconsin age, clearly separated from two high systems of Illinoian age. As in the Hocking Valley, the systems are identified by profiles (fig. 3) and soils (fig. 4). Stone-counts generally do not differentiate the various levels of outwash except to substantiate former connection of a few adjacent Wisconsin terraces. Detailed mapping of the Scioto Valley terraces was limited by time. However, a reconnaissance of the whole outwash drainage together with unpublished county studies establishes a fairly accurate picture of the valley train deposits.

Illinoian stage.—Illinoian outwash occurs as large, generally flat-topped remnants over an extensive area east and southeast of Chillicothe (fig. 5). These remnants are present along and between the small valleys of Lick Run, Dry Run, and Walnut Creek, along the east side of the Scioto Valley opposite Chillicothe, and in the abandoned preglacial Teays Valley in the vicinity of Londonderry and Vigo. Others extend southward to Richmondale in the Scioto Valley about two mi north of the Ross-Pike County line. Illinoian outwash appears to be absent along the Scioto Valley just north of Higby. However, there is a rather prominent remnant of Illinoian outwash near the mouth of Paint Creek to the north, as well as scraps present along a small valley in the western part of Chillicothe and along the Scioto Valley wall just west of town. This suggests that the main Illinoian outwash or entire flow passed eastward down the now abandoned old Teays Valley at Vigo.

Along the Scioto between Higby and Waverly, extensive plains of Illinoian outwash averaging about a mile in width cover an area of more than five mi^2. These terraces cover the bedrock floor of another isolated lateral segment of the old Teays Valley along the western flank of the present Scioto Valley. At Waverly the northward sloping bedrock surface of the Teays Valley apparently is just above the Illinoian outwash, the two profiles crossing at about 650 ft elevation just northeast of Waverly (fig. 3). Southeast of Waverly (fig. 5) the old Teays Valley lies in a broad bend with a gradual rise in elevation of the bedrock floor (Lockwood, 1954) so that no definite evidence of Illinoian outwash can be found.

Down the present Scioto River, between Waverly and Portsmouth, Illinoian outwash is represented only by small rounded knobs and a few narrow flat-topped

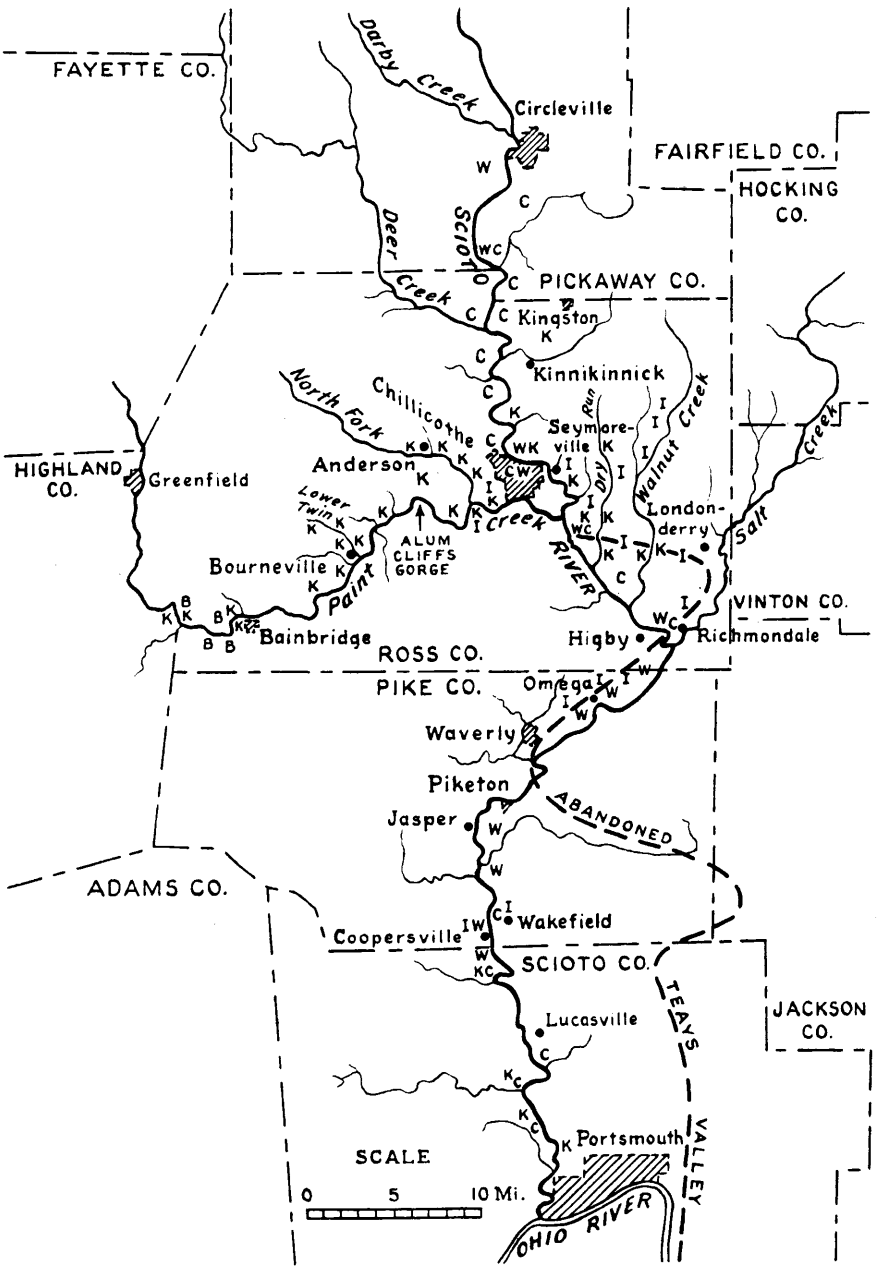


FIGURE 5. Map of lower Scioto River and portions of major tributaries, showing approximate location of larger terrace remnants: I, Illinoian; B, Bainbridge; K, Kingston; C, Circleville; W, Worthington.

remnants along the sides of the valley; considerable difficulty is encountered in locating them.

Patches of water-laid material, including calcareous sands, were found at elevations too high to be considered Illinoian (fig. 3). These may be deposits of the Teays River or the northward flowing preglacial tributary of the Teays, the Portsmouth River, which flowed in essentially the same position as the present Scioto south of Piketon (Stout et al., 1943). However, the possibility that some of this material is glacial, but of pre-Illinoian age, cannot be overlooked.

As in the Hocking Valley, there is evidence of two levels of Illinoian outwash (fig. 3). Both Hyde (1921) and Leverett (1942) mention two levels. The higher terrace level may be present along Walnut Creek far east of Chillicothe, but it is more apparent on the eastern side of the Scioto Valley just opposite Chillicothe where it heads at an elevation of 875 ft at the settlement of Seymoreville. This is thought to be a kame terrace though no kettle holes remain. The rather maturely-dissected remnants of this level extend for about five mi south of Seymoreville along the eastern side of the Scioto Valley. The lower level heads along Walnut Creek and also in lower Paint Creek west of the Scioto Valley. It is present as scattered narrow remnants southward along Walnut Creek to the abandoned Teays Valley in which an extensive southeastward sloping pitted outwash plain is developed. The kettle holes are only obscure shallow filled depressions in the field but are very obvious on aerial photographs.

Although the profiles indicate two levels continuing down valley, the identity of two surfaces is lost, particularly below Waverly, and they may converge as suggested for the two Illinoian levels in the Hocking Valley (fig. 3). Between Higby and Waverly two levels are present, the higher, close to the bedrock walls, being about ten ft above the more extensively developed lower surface. The fact that exposures and wells show that the bedrock floor is only 20 to 30 ft below the entire gravel terrace would tend to eliminate the alternate explanation of settling, such as might be expected in a deeper gravel fill.

The major portion of the Illinoian outwash is composed of fairly coarse sand and gravel. In general the higher outwash level heading at Seymoreville is composed predominantly of rather silty sand with some gravel while the lower level outwash appears to be composed of much coarse and cleaner sand and gravel beds. This distinction has not been noted south of Londonderry.

The depth and character of the soils (fig. 4) developed on these terrace remnants, where exposed or interpreted from well logs and auger borings, appears similar to soils developed on the Illinoian terraces in the Hocking Valley. About a mile west of Londonderry the following sequence is exposed in the lower terrace level (Goldthwait, 1955):

		Ft
4.	Weak upper soil profile in silts (loess) "early" Wisconsin	3–5
3.	Buried gray A-zone of humic gley in sands, Sangamon	2
2.	Reddish B-zone, Sangamon, leached	6
1.	Calcareous sandy gravel, Illinoian	3–9

There is some suggestion that the higher terrace is more deeply leached and oxidized. This was noted by Hyde (1921). But, as in the Hocking Valley, the total length of time during which all soil formation has progressed renders differentiation of substages on this basis difficult, particularly with the apparent different mechanical compositions of the parent outwash material of the two levels.

The bases of relating these high terrace systems to the Illinoian stage is the same as for the Hocking Valley. The source of these systems is inside the limits of the farthest advance of Illinoian ice into the Teays Valley in Ross County but not within Wisconsin drift limits. As indicated by figure 4, the soils developed on the outwash remnants are considerably deeper than on terraces of Wisconsin

age, but are similar to the soils developed in the Illinoian outwash of the Hocking Valley. Also, the elevations of the Illinoian terraces are 20 to 190 ft higher than the highest of those emanating from the area of Wisconsin drift to the north. This indicates an interval of erosion of the Illinoian valley train prior to the deposition of various Wisconsin valley trains. The greater steepness of the gradient of nearly 30 ft per mi, toward the source of the outwash in the bedrock hills east of Chillicothe, is indicative of nearness of the ice, and since only Illinoian ice-laid deposits have been recognized within the hills, the outwash also must be regarded as Illinoian in age. (It might be noted that Hyde [1921] postulated an "early" Wisconsin age for the lower Illinoian level, based primarily on what appeared to him to be deeper weathering of the higher level along with the more mature dissection. The lower level appeared to him to be less dissected, with a shallower weathering profile and preservation of a pitted surface in places. It is felt here that the finer texture and poorer sorting of the higher level outwash may give the impression of a deeper weathering profile. Also greater initial slopes of the higher level may have initiated more rapid erosion than on the broad flat lower level, thus leaving the higher level in a more advanced stage of dissection at present.)

Illinoian outwash is also mapped west of Bainbridge along the Ross-Highland County line above Paint Creek (Foster, 1950) heading at an elevation of about 975 ft. It was carried southward into the area now called Beech Flats near Cynthiana and possibly into the Baker Fork-Ohio Brush Creek drainage. There is no evidence of a connection with Scioto River drainage.

Wisconsin stage.—Three levels of outwash and a possible fourth originating from within the Wisconsin drift boundary are identified in the Scioto Valley and several tributaries (fig. 3). These terrace levels are generally readily distinguished north of Chillicothe but become more difficult to identify between Waverly and Portsmouth. Together they form a suite of profiles well below the level of the Illinoian terraces.

A local system of silt terraces (Bainbridge) is found just west of Bainbridge in the Paint Creek Valley (fig. 5). Falling some 165 ft below the Illinoian terraces and 50 ft above terraces with good Wisconsin Fox soil profiles these are believed to be of "early" Wisconsin age. Careful acre-by-acre mapping of the soils by the Ohio Division of Lands and Soil Survey (Petro, personal communication) indicate the presence of affiliated "early" Wisconsin till and ice contact deposits south and east of Bainbridge. Since there is no extension of this level down valley and because grains are of lacustrine size, these are thought to represent slackwater deposits accumulated in "early" Wisconsin time along decaying ice which squeezed into both ends of Paint Creek Valley. Nearby mollusc bearing lacustrine deposits at Humboldt (Reynolds, 1959) confirm a lake, and deep Williamsburg soils in the silt confirm preconventional Wisconsin age. At 1.7 mi west of Bainbridge an auger hole penetrated eight ft of this soil and silt, then passed again into reddish weathered sand; this is interpreted as Sangamon soil under a silt terrace remnant.

The highest extensive Wisconsin terrace system heads in eastern Ross County at a kame terrace group about two and one-half mi southwest of Kingston and east of the Scioto Valley at an elevation of 725 ft (figs. 3 and 5). For this reason it is called the Kingston terrace. It appears to join an esker chain which is present in discontinuous segments along the eastern side of the Scioto River beginning just south of Columbus. Various lines of evidence suggest that the terrace system is actually younger than the esker and not genetically attached; the esker extends past the terrace near Kingston toward ice contact deposits south of Kinnickinnick. Near Kingston there are a few tiny kettles suggesting proximity to ice and lack of matching high terraces west of the Scioto is argument for ice contact in this area. Patches of this terrace system are present along the eastern side of the Scioto Valley from three mi north to about five mi south of Chillicothe and in the valleys of Walnut Creek and possibly Dry Run entering from the east and Paint Creek

entering from the west (fig. 5). The remainder of the length of the Scioto Valley apparently contains only small remnants of the Kingston terrace system although positive identification is impossible due to the scarcity and small size of the remnants present.

Identification of remnants of the Kingston system in the Scioto Valley in the vicinity of Chillicothe was based on the presence of an Ockley soil: silt over gravel, with a reddish-brown clayey B horizon and an irregular pendant structure at the base of the leached and weathered gravel (fig. 4). The capping of silt and fine sand averages about 18 in. although as much as 30 in. occur at a few localities. The depth of leaching and oxidation was generally about 50 to 60 in., including the silt capping. The soils developed on the Kingston outwash level in Paint Creek differ from those along the Scioto near Chillicothe in that the former lack the fine silt and sand capping and have a deeper brown color, with a more gradational change from the weathered to unweathered sand and gravel. Depths of leaching here generally range from 36 to 48 in.

In addition to soils, the elevations of the terraces aid in the identification of the Kingston system (fig. 3). The terraces in Paint Creek Valley are somewhat complicated for representation on this profile due to outwash fan building from Lower Twin Creek Valley, the presence of the narrow Alum Cliffs Gorge diversion, and the moraine and outwash block at the northeast end of the old valley, near Anderson. In these areas the Kingston terraces with Wisconsin Fox soils fall into two levels. Some higher ones near Bourneville tie to sloping terraces up Lower Twin Creek and seem to project to the broad outwash crest at the valley mouth south of Anderson; presumably this water came down Lower Twin Creek and passed to North Fork Paint Creek after the ice freed this northerly route. A level about 20 ft lower (projected) comes from west of Bainbridge and may have passed through Alum Cliffs Gorge although it is possible that it merged with the upper level east of Bourneville. A terrace preserved at the lower end of the gorge indicates that some outwash took this route, with a final merger into one Kingston level at the present junction of North Fork and Paint Creek.

The material of the Kingston outwash system is composed of medium and coarse sand and gravel. In the Scioto Valley approximately 75 to 80 percent of the one to three-in. pebbles are calcareous rock types while in Paint Creek Valley the count is close to 90 percent, predominantly dolomite. No logs were available from wells drilled in these terraces and, thus, there is not stratigraphic information available suggesting the maximum thickness of the outwash.

The outwash, which comprises the terraces of intermediate Wisconsin level, here named Circleville, heads at the southeastern edge of Circleville in Pickaway County at the outer margin of the Marcy moraine. At its source the Circleville terrace is a rather extensive pitted outwash plain. Numerous kettle holes, large and small, are visible over much of the first four mi of the sloping surface. From Circleville to about eight mi south of Chillicothe, smaller terrace remnants are numerous and cover considerably more area than those of the other Wisconsin outwash systems. The main business district of Chillicothe city rests on this terrace. The only tributary which contains outwash of the intermediate level is Deer Creek in Northern Ross County. This apparently is present only as one remnant on the north side of Deer Creek Valley near its junction with the Scioto River in Ross County.

Remnants of this middle outwash system were identified mainly by their position on the profile (fig. 3) and by the soil character and depth of leaching (fig. 4). The diagnostic soil characteristics are a reddish-brown, clayey B horizon with a sharp, irregular pendant structure at the base. Total depth of oxidation and leaching averages 34 in. and varies from about 30 to 40 in. due to the pendants.

The outwash materials of this system are composed of sand and gravel, with

cobbles up to 10 to 12 in. not uncommon. It differs from Kingston terraces by its lack of loess cover. As in the case of the other terrace levels in the Scioto Valley, no unique pebble count identified this level; there were about 75 to 80 percent of carbonate pebbles among one hundred, one to three in. in length. Well logs record sand and gravel at least as deep as 117 ft under the surface of these terraces in the vicinity of Chillicothe, with no stratigraphic break indicated.

The lowest terrace system in the Scioto Valley is traced to just north of the junction of the Olentangy River with the Scioto at Columbus in Franklin County. Terraces of this level head near the Powell Moraine; remnants may be present as far north as Worthington along the Olentangy River and thus, it will be called the Worthington terrace system. Outwash of the same level and age appears to be present also in the valley of Big Darby Creek, and its tributary Little Darby, which enters the Scioto from the northwest at Circleville and also in the valley of Deer Creek (fig. 5). Patches of these low terraces are generally large and rather numerous between Columbus and the Ross-Pike County line, but further south are smaller and fewer in number.

The soils are similar to those developed on the intermediate terrace level, but differ in depth; the average depth of leaching and oxidation depth is 24 in., with a variation of from about 20 to 32 in. (fig. 4). As in the case of the other terrace systems, elevations of presumed remnants of this system plotted down valley aid in their identification (fig. 3).

Silt terraces.—Several silt terraces are present in the main Scioto Valley south of Chillicothe, particularly in Scioto County. They fall generally below the level of the Worthington terraces, although a few are present at or above this level (fig. 3). These might ordinarily be considered cut-and-fill terraces, as found in numerous places both in the Hocking and Scioto Valleys, but certain aspects raise a question as to their origin and age. These terraces generally consist of at least seven to nine ft of highly weathered acid silt and fine sand overlying sand and gravel. In a pit at the Pike-Scioto County line the upper one to three ft of the underlying gravel was generally oxidized and noncalcareous. The same acid silt and fine sand are also present over much of the floor of the valley of Walnut Creek and perhaps others. Markland catena soils are mapped here.

One critical exposure at the settlement of Coopersville, (west bank of Scioto River, extreme south edge of Pike County) displays sand and gravel (probably Worthington terrace) over silt. The lack of well logs in other areas near exposed silt deposits has made it impossible to determine whether or not similar silt underlies the gravels of the outwash terraces elsewhere. The lack of siliceous grit makes it appear that the silt and sand has not been derived from the intense weathering of sand and gravel, so it may be more reasonable to consider these terraces as floodplain deposits derived from the erosion of acid soils and rocks in the vicinity. These must have been formed in Sangamon or earlier time.

Lacustrine deposits.—Lacustrine deposits were noted mainly in the valleys tributary to the Scioto south of Chillicothe and in Paint Creek Valley as previously mentioned. These deposits are present in the valleys of Salt Creek, north of Richmondale, and in many other valleys to the south. They apparently were formed when one or more of the Illinoian or one of the Wisconsin valley trains dammed these valleys. These deposits consist of massive to finely laminated beds of clay, silt, and sand.

The valley of Indian Creek, a tributary to the Scioto Valley from the southwest about three mi south of Chillicothe, contains a very interesting lacustrine deposit exposed between Massieville and its mouth. The construction of a new highway (U. S. 23) has recently provided excellent exposures of varved clay which apparently accumulated during the time when an ice tongue, extending down the main Scioto Valley, blocked the mouth of the side valley. Striae found on bedding surfaces of the Devonian Ohio black shale along the west side of the Scioto Valley

just north of the junction of the Indian Creek Valley appear fresh enough to be evidence for a Wisconsin ice tongue. Also the fact that remnants of Illinoian terrace gravels are present much higher along the northwest side of the valley would suggest that the varved sediments were deposited after the Illinoian outwash had been removed by Sangamon erosion. Soils on the upper silt vary from 40 to 60 in. deep but lack much development; best guess is that they are early Wisconsin. (Hyde [1921] believed these to be Illinoian varves since he considered that only a tongue of Illinoian ice could penetrate far enough down the Scioto Valley to block Indian Creek Valley.)

Significance of The Outwash Terraces

Pre-Illinoian stage.—The presence of at least two very old terrace remnants in the Hocking Valley at a higher elevation than Illinoian outwash, and on which a deeply weathered red soil is developed, may be evidence of pre-Illinoian outwash. These remnants add to evidence under study in the Cincinnati region of a Kansan (?) glacier reaching south-central and southwestern Ohio (Durrell, 1958). Although no glacial deposits definitely considered pre-Illinoian were found in the Scioto Valley, the water-laid sediments at elevations above the Illinoian terraces (fig. 3), thought to be deposits of the Teays River and Portsmouth River of Teays Stage, may in fact be pre-Illinoian glacial terrace deposits. The blocking of the Teays River system itself (Stout et al., 1943) is still considered to be due most probably to a pre-Illinoian glacier.

Illinoian stage.—Probably the most striking feature of the Illinoian terrace remnants in both the Hocking and Scioto Valleys is the presence of two distinct levels of outwash in both valleys, at least in their upper portions. Whether or not these two levels are actually present nearly all the way to the Ohio River in each valley is a matter for detailed leveling and discrimination. Leverett (1942) relates both levels to the Illinoian stage and suggests that an ice dam in the Cincinnati region provided a temporary ponding, resulting in the formation of the higher level; then, with its removal, the lower level was formed. The profiles (fig. 3), however, suggest that the two levels in each valley may merge to essentially one level near the Ohio River. This makes a Cincinnati ice dam unlikely as a controlling factor in the formation of two levels. All terrace levels were controlled by the load and hydraulics of the issuing streams at the ice edge.

A possible added interpretation is that the high and low levels in each valley were formed during separate ice advances of sub-stages of Illinoian time. The fact that each level heads in a different valley area is some argument that each Illinoian terrace level represents a different stage of advance of Illinoian ice. For example, the first high Illinoian outwash down the Hocking Valley headed two and one-half mi southeast of Lancaster and the second, lower Illinoian headed at the southeast edge of Lancaster, perhaps up Rush Creek and far west up Clear Creek. The first high Illinoian outwash down Scioto Valley headed just east of Chillicothe while the latter was farther east up Walnut Creek. Perhaps the strongest suggestion of two stages of the Illinoian is in the E ½ Sec. 21 and the W ½ Sec. 22 Springfield Township, Ross County (two mi east of Chillicothe between Lick Run and the Scioto Valleys) where Illinoian till actually lies over gravels contiguous with the higher Illinoian outwash; here the ice readvanced after the upper outwash was completed, but not as far as before.

Sangamon stage.—The deep, red brown to yellow brown soils developed on the Illinoian outwash terraces of both valleys are evidence of a long period of weathering and are considered typical of the soils developed on gravel in this region primarily during the Sangamon Interglacial Stage. That some of the development of soil continued into late- and post-Wisconsin time is evident in the cover or uniformly graded silt now recognized as loess. It extends onto older Wisconsin terraces as well, so this must be mostly Wisconsin loess and the present

soil on Illinoian terraces is redeveloped through the younger cover. The total profile is polygenetic. In the deeper silt soils, called Pike (Chillicothe), this is recognized in actual double profile. A Sangamon profile in loess is buried at four to six ft depth.

Another feature very evident is both valleys is the tremendous amount of Illinoian outwash that was removed prior to the deposition of the Wisconsin valley trains. This trenching of the Illinoian outwash is believed to have occurred during Sangamon time although the possibility exists of deepening by torrential waters from the advance of the earliest Wisconsin ice. There is no other evidence of enough Wisconsin meltwater to accomplish such a task in so short a time and much of the dissection is in side valleys heading scores of miles away from the site of Wisconsin meltwaters. The great dissection must be a measure of Sangamon time especially where lower Wisconsin terraces fill the cut.

Early Wisconsin substage.—The intermediate depths of Rush soil on the Lancaster terrace system and the scraps of higher terrace with intermediate soil profile (Williamsburg catena) in Paint Creek Valley all point to a post Sangamon glaciation prior to conventional Wisconsin substages. One might seek alternate explanations for the deeper soils on Wisconsin terrace levels, but neither texture nor lithology and certainly not climate indicate any reason. Variations in loess to a maximum of 30 in. were not found to make any significant difference here although an important variable elsewhere (Gooding, 1957). Carbonate content is similar in Lancaster and Carroll levels. On the other hand, Forsyth and La Rocque (1956) find evidence in superimposed drifts indicating an "earlier" Wisconsin; Goldthwait and Burns (1958) have interpreted buried soils and vegetation within the upper drift as a long mid-Wisconsin interval ending 18,000 to 25,000 yr ago (C^{14} dating). Thus, these terraces add to the accumulating evidence for a glacial phase of the Wisconsin Stage in Ohio prior to 30,000 yr ago.

The silt cover one and one-half to five ft deep on Illinoian, Lancaster, and Kingston terraces is interpreted as loess. Its mechanical composition shows excellent sorting since 60 to 80 percent of the grains falls between 0.002 and 0.05 mm diameter. (Courtesy of Soils Laboratory, Department of Agronomy, The Ohio State University.) Occasional pebbles, especially near the base, are interpreted as raised by frost, tree roots, or plowing; this is common in the Mississippi Valley. That this loess is rather thick on these Illinoian and higher Wisconsin terraces and missing on Carroll, Circleville, and Worthington terraces suggests that the principal dust storms were during the early Wisconsin before 30,000 yr ago and partly just after the development of the Kingston terrace. Although the loess has not been divided into stratigraphic units thus far, it is true that in any one valley loess on Illinoian terraces is deeper than that on early Wisconsin terraces. These in turn have more than Kingston terraces—but the capping on all is clearcut. Thus, we conclude that some aeolion deposit was begun in late Illinoian time, more was added after early Wisconsin, and the final foot or two were added just after the Kingston terrace but before Carroll or Circleville were completed.

Late Wisconsin substages.—The "late" (conventional) Wisconsin involves four main terrace substages. Two (Carroll and Circleville) may be simultaneous.

First and highest are the Kingston terraces, over 30 ft above all other Wisconsin levels north of Chillicothe. Since the northern-most remnant in the Scioto Valley is just north of the terminal moraine traced generally to the Cuba moraine (outer Wisconsin of Scioto Lobe) and since the accordant levels down Dry, Walnut and Paint Creeks come from the terminal moraine, it is held that this outwash formed during and just following the outer moraine formation, probably Cuba Moraine time (fig. 1). Elsewhere it is dated 17,000 to 18,000 yr ago (Burns and Goldthwait, 1958) but at present the most likely tie to type moraines in Illinois is Tazewell. The loess cover and relatively deep soil make it similar to Tazewell

terraces farther west. Even when this terrace building finished, ice still filled the Scioto Valley down to Chillicothe because there is not a matching level on the west side; near Kingston these were actually kame terraces and indeed there is a small kettle or two.

Second, and actually lowest in Hocking Valley, are the Carroll terraces. These tie by kettles and steepened gradient and kame terraces to the Carroll moraine ten mi within well known Wisconsin drift. That they have no loess cover suggests that they are later than the Kingston terrace, but there is loess on adjacent Wisconsin ground moraine through which Carroll outwashes passed. On the other hand, relatively deep Fox soil (48 in.) is more comparable to Kingston than to later Scioto terraces. Moraines are little help in settling this paradox of intervalley correlation, for the Carroll moraine is lost on highlands to its west. It seems by projection to predate the Marcy Moraine at Circleville which has been tentatively correlated with the Reesville Moraine farther west (fig. 1). The alternate and tempting hypothesis is that the Carroll and Marcy moraines are one in time and both produced simultaneous silt-free outwashes from Carroll and Circleville. But the Circleville outwash has a shallower soil profile and both are in uniform sand and gravel!

Third, then, is the Circleville terrace system. Prior to its deposition, readvancing ice stood along irregular moraine hills west of Kingston, and channels were cut out of the Kingston kame terrace at Kinnikinnick. As the ice retreated by undercutting of Scioto waters, the lower extensive valley fill called Circleville was built up from side to side across the whole valley. That accordant terraces extend only three mi up Deer Creek and not at all in Darby Creek indicates that there was ice covering these areas and the ice edge thus seems to correlate with Reesville Moraine. This in turn is tentatively correlated with the Bloomington Moraine of Illinois.

Fourth and last is the Worthington terrace system which while it converges toward older terraces downstream, is about 50 ft lower at Circleville and extends far up the Scioto and Olentangy Rivers to six mi north of Columbus. Kettles are present near Columbus. This is near to, but not at, the Powell moraine but, since accordant terraces reach up Darby Creek almost to the same moraine (yet not up Deer Creek), ice must have been about there. By latest tentative correlation this may be the time equivalent of the Minooka Moraine of outermost Cary Substage in Illinois.

ACKNOWLEDGMENTS

A number of persons have aided greatly in various phases of the field investigations connected with this paper. Dr. Nicholas Holowaychuk, The Ohio State University, and Mr. James H. Petro, Ohio Division of Lands and Soils, have supplied soils information. Dr. Jane Forsyth, Ohio Geological Survey, has discussed many of the problems connected with this study and has aided in the preparation of the Glacial Map presented. Dr. Myron T. Sturgeon, Ohio University, supplied information available at Ohio University on the Lower Hocking Valley in Athens County. Margaret Castle, Illinois Geological Survey, drafted figures two through five. Mr. Harold J. Flint, Ohio Geological Survey, drafted figure one.

The field studies were made as part of a program of the Ohio Division of Water, Department of Natural Resources, to collect basic data on the Pleistocene deposits of Ohio. Funds were made available by the Development Fund of The Ohio State University to support phases of the work in the Hocking Valley.

LITERATURE CITED

Andrews, E. B. 1860. Relation of the river terraces of southern Ohio to the drift and drift theories. Proc. Amer. Assoc. Adv. Sci. 13: 319–321.

———. 1874. Drift in the second geological district. Report Geol. Survey Ohio. 2: 441–452.
Conley, J. F. 1956. Glacial geology of Fairfield County, Ohio. Unpublished Master's Thesis, The Ohio State University.
Durrell, R. 1958. Two occurrences of buried Kansan till in southwestern Ohio, Title, paper, Ohio Acad. Sci., Program, 1958.
Forsyth, Jane L. and **A. LaRocque.** 1956. Age of the buried soil at Sidney, Ohio (abstract). Geol. Soc. Amer. Bull. 67: 1696.
Foster, J. W. 1950. Glaciations and Ice Lake of Paint Creek Valley, Ohio. Unpublished Masters Thesis, The Ohio State University.
Goldthwait, R. P. 1955. Pleistocene chronology of southwestern Ohio; Guidebook, Fifth Biennial Pleistocene Field Conference. Ohio Div. Geol. Survey, pp. 35–72.
——— and **G. W. Burns.** 1958. Wisconsin age forests in western Ohio. Ohio Jour. Sci. 58: 209–230.
Gooding, A. M. 1957. Pleistocene terraces in the upper Whitewater drainage basin. S. E. Indiana Sci. Bull. No. 2, Earlham College.
Hubbard, G. D. 1954. Terrace interpretation in southeastern Ohio. Ohio Jour. Sci. 54: 365–377.
Hyde, J. E. 1912. The Geologic History of Fairfield County, Ohio. Extract from History of Fairfield County and Representative Citizens, by Charles C. Miller, pp. 203–223, Richmond-Arnold Pub. Co., Chicago, Ill.
———. 1921. Geology of the Camp Sherman quadrangle. Ohio Geol. Suvey Bull. 23.
Kempton, J. P. 1956. Outwash terraces of the Hocking River Valley, Ohio. Unpublished Master's Thesis, The Ohio State University.
Leverett, F. 1902. Glacial formations and drainage features of the Erie and Ohio Basins. U. S. Geol. Survey Mon., Vol. 41.
———. 1942. Gravel outwash near Chillicothe, Ohio. Science 95: 528–529.
Lockwood, W. N. 1954. Progress Report on subsurface study of the Teays River Valley sediments in Pike, Jackson, and Scioto Counties. Unpublished report to Ohio Div. Water, Dept. Nat. Res., 27 pp.
Merrill, W. M. 1950. The geology of northern Hocking County, Ohio. Unpublished Doctor's Thesis, The Ohio State University.
———. 1953. Pleistocene history of a part of the Hocking River Valley, Ohio. Ohio Jour. Sci. 53: 143–158.
Paschall, A. H., J. G. Steel, F. G. Loughry, and **G. W. Conrey.** 1958. Soil survey, Athens County, Ohio. U. S. Dept. Agric.
Reynolds, M. B. 1959. Pleistocene molluscan faunas of the Humboldt deposit, Ross County, Ohio. Ohio Jour. Sci. 59: 152–166.
Schmidt, J. J. 1958. The ground-water resources of Franklin County, Ohio with section on glacial geology by R. P. Goldthwait. Ohio Div. Water, Dept. Nat. Res., Bull. 30, 17–21.
Schuster, R. L. 1952. The glacial geology of Pickaway County, Ohio. Unpublished Master's Thesis, The Ohio State University.
Sterns, C. H. 1899. Some observations on the topography of Athens and vicinity. Ohio State Acad. Sci. 7th Ann. Rept. pp. 67–70.
Stout, W. E. and **G. F. Lamb.** 1938. Physiographic features of southeastern Ohio. Ohio Jour. Sci. 38: 49–83.
Stout, W. E., K. Ver Steeg, and **G. F. Lamb.** 1943. Geology of water in Ohio. Ohio Geol. Survey Bull. 44.
Tight, W. G. 1900. Drainage modifications in Washington and adjacent counties. Ohio Acad. Sci. Spec. Paper No. 3: 11–31.
———. 1903. Drainage modifications in southeastern Ohio and adjacent parts of West Virginia and Kentucky. U. S. Geol. Survey Prof. Paper No. 13.
White, G. W. 1939. Illinoian drift of eastern Ohio. Amer. Jour. Sci. 37: 161–174.